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Minister of Fisheries

Juvenile Sockeye Studies in Owikeno Lake, British Columbia

by

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Abstract

The results of a four-year study of juvenile sockeye salmon abundance, distribution, growth rate and survival in various regions of a British Columbia coastal lake, along with data on water temperature, transparency and zooplankton abundance, are presented. Results indicate that an inverse relationship exists between population density of young salmon and their growth rate and survival. The density dependent nature of these relationships suggests that food and/or space act as a population control limiting smolt production in Owikeno Lake. No significant relationship was found between juvenile sockeye lacustrine growth or survival and zooplankton abundance.

Introduction

Owikeno Lake, on an area basis, is one of the most productive sockeye salmon (*Oncorhynchus nerka*) lakes in North America. This coastal British Columbia lake system constitutes the spawning and rearing area for the stock of sockeye salmon on which the Rivers Inlet commercial salmon fishery is based. This fishery has harvested, during the period 1912 to 1963, an average annual catch of approximately one million sockeye salmon with a range of between 420,000 and 1,918,000.

In 1960, studies were initiated on the freshwater phase of the Owikeno Lake sockeye salmon stock as the first stage in a proposed investigation being developed to provide the basic requirements for scientific management of this stock. The program on the freshwater phase included studies on relative abundance, growth rate, survival and distribution of juvenile sockeye within the various regions of Owikeno Lake.

Data on water temperature, transparency and zooplankon abundance are provided to document certain of the limnological variables believed to be important in the dynamics of sockeye smolt production. The results of these studies during the four-year period 1960 to 1963 inclusive are described in the body of this paper.

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Description of Watershed

Owikeno Lake (Figure 1) is a piedmont lake of glacial origin occupying a cryptodepression 1200 feet deep. The surface elevation is less than 50 feet and a small rise in sea level would convert it into an arm of the sea. The lake is deep, cold and typically oligotrophic. It is composed of a chain of four distinct basins, each of which is separated by a relatively shallow narrows. Basins 1 and 2, the lowermost basins, comprise over 90 percent of the total lake area and are characterized by extreme depths, exposure to strong winds and high turbidity. In contrast, the upper two basins, numbered 3 and 4, comprise less than 10 percent of the lake area and are shallow, sheltered from the prevailing winds and are considerably less turbid. The lower basins do not freeze over during the winter, while the upper basins often are ice-covered for a 2 to 4 month period. The 3 mile long Wannock River connects the lake to Rivers Inlet.

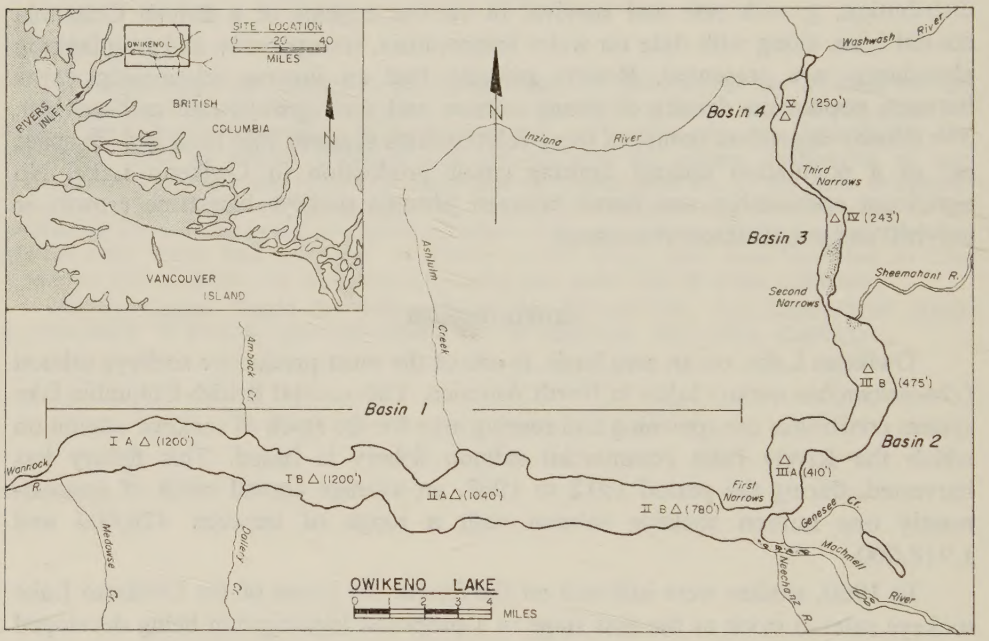

FIGURE 1. *Location map of Owikeno Lake.*

Some of the available dimensions are recorded below:

Length—35 miles
Area—37 square miles
Maximum depth—1210 feet
Surface elevation—46 feet
Drainage area—1600 square miles

Most of the streams, tributary to Owikeno Lake, are precipitous and several carry large quantities of glacial silt. The two largest tributaries, the Machmell and Sheemahant Rivers originate in large ice fields and contribute the bulk of the silt load to the main lake basin. Run-off, in general, is rapid and accounts for spectacular changes in lake level. The lake is situated in a remote region and is as yet not affected by agriculture, industrial development or logging.

Characteristics of the Stock

Adult sockeye salmon spawn in beach areas located within Owikeno Lake, in streams tributary to the lake and in the Wannock River which drains the lake. Spawning occurs during the period September to early December, and following a winter incubation period, the resulting fry emerge, enter the lake during April and May and take up residence in the pelagic region. The seaward migration generally occurs after one year of lake residence although a small proportion of juveniles remain in the lake for an additional year. Adult sockeye return to this system in their fourth or fifth year after 2 or 3 years of ocean residence.

Methods and Equipment

Juvenile sockeye salmon were sampled by means of a 3-foot diameter net towed behind two boats (Johnson, 1956). The forward 6 feet of the net was constructed of 5/8-inch nylon netting, while the 3-foot bag end was made up of nylon marquisette with openings of approximately 5/32 inch. The net was towed on 1/4-inch nylon lines 100 feet long attached to two 18-foot outboard motor-powered boats which were operated on a parallel course and at an approximate speed of 8 miles per hour. In this manner the net sampled the surface 3 feet of the lake. Collections were made from five regions within the lake; two in the large, lowermost basin and one each in the remaining three basins (Figure 1).

Because of the greater success in capturing fish at the surface during the interval between dusk and early darkness, the following routine method of sampling was adopted: three consecutive 20 minute surface tows were made spaced by 10 minute intervals between tows in order to provide time for emptying the catch from the net. The starting time was governed by reflected sky light as measured by a General Electric light-meter with a 5 foot-candle sensitivity. The first tow of each night was started when the meter registered between 5 and 0 foot-candles of reflected sky light. These three 20 minute tows were used as the unit of fishing effort. Each region was sampled four times per month over the sampling period April to October, inclusive.

This technique, therefore, sampled between 7 and 8 lineal miles of lake surface during each unit of effort. Catches during a unit of fishing effort varied between zero and 4000 fish. The catch per unit of effort is expressed in fish per acre by the use of a factor determined by Johnson (1958) based on sampling by this technique

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in a lake where the approximate population density was known. Although the limitations of applying this factor to Owikeno Lake data are realized, the calculation is considered useful on the basis that it indicates the general order of magnitude of the populations involved. On the basis of Johnson's findings, a factor of ten was used to convert the catch per unit of effort to fish per acre.

Samples from each catch were preserved in a 10 percent formalin solution and weighed and measured 10 to 16 hours later in a standardized manner.

In order both to evaluate the variations in catch per unit of towing effort and to calculate summer survival, a series of regressions of log catch on time were calculated for each towing station. A summary of this regression analysis is presented in Table I of the Appendix.

Limnological sampling was carried out at eight stations, distributed so as to provide data descriptive of each of the juvenile sampling regions. Four sampling stations were established in basin 1, two in basin 2 and one each, in basin 3 and 4 (Figure 1). Limnological data were collected twice each month, during the period April to October, inclusive.

Temperature data were gathered by means of a bathythermograph and an electrical resistance thermometer.

Transparency was measured by observing the depth at which a white secchi disc 20 centimeters in diameter just disappeared from view.

Zooplankton was collected with a No. 10 mesh net of silk bolting cloth with a mouth diameter of 25 centimetres. Both Ricker (1938a) and Ward (1957) have shown that the sampling efficiency of nets fitted with straining cones of No. 10 bolting silk does not vary significantly over long periods of continuous use. The practice in the present study was to use a new net at the beginning of each year, or more often if nets became damaged.

At several of the limnology sampling stations the depth exceeded 328 feet (100 metres) and the routine sampling procedure entailed making a vertical haul from the 100-metre depth to the surface. Where the depth at a station did not exceed 100 metres (basins 3 and 4) the vertical haul was made from a position just off the bottom to the surface. Rate of haul was approximately one metre per second. Three hauls were made on each visit to a station, and this method provided two duplicate samples; one to be dried, weighed and ashed and the other to be examined for qualitative and numerical counts. In order to overcome the error which might occur from the fact that varying amounts of glacial silt were present in the samples, only the organic matter is considered in the quantitative analysis of the zooplankton. This also reduced the effect of the occurrence of diatoms in the hauls, since these minute plants are roughly 40 percent ash, whereas the ash content of zooplankton ranges from 6 to 25 percent depending on the species present (Birge

and Juday, 1922). The catches per haul have been converted to pounds per acre, on the basis of a 91 percent net efficiency. This net efficiency was adopted from Ricker (1938b) based on many tests with similar nets.

Results

Juvenile Sockeye Abundance

The relative abundance of 0 age sockeye juveniles was calculated on the basis of tow-net catches made during the period from late June, at which time all the fry were believed to have entered the lake and taken up residence in the pelagic region, until early November. The relative abundance of pre-smolt juveniles was calculated from tow-net catches made from late March to the end of April, after which time a general and easily identifiable smolt movement began in the direction of the lake outlet. In both cases the geometric mean catch for each basin, during the time period involved, was converted to fish per acre and a weighted mean, based on the area of each basin, was calculated.

Juvenile sockeye abundance in fish per acre is summarized in Table 1.

Table I

The Mean July to October Juvenile Sockeye Abundance in Fish Per Acre for the Years 1960 to 1963 Inclusive.

Year	Basin 1	Basin 2	Basin 3	Basin 4	All Basins
1960	6690	8880	8290	6180	7170
1961	3640	2880	970	1990	3324
1962	4105	2210	4510	2970	3679
1963	1945	3170	2940	2240	2242
Means	4094	4285	4178	3345	4103

The number of juveniles rearing in the individual basins of Owikeno Lake has varied between 970 and 8880 fish per acre. In 1960, the density of rearing juveniles was fairly even over all regions of the lake, but in the other years considerable differences in densities occurred between basins. In general, the relative concentration of juveniles appears to reflect the size of the spawning escapement of adults in the streams tributary to the respective lake basins. The "all basin" data has been weighted by the area of each lake basin and represents the average density of juveniles for the lake as a whole. The summer density in Owikeno Lake over the four study years has varied between approximately 2000 and 7000 fish per acre.

The juvenile sampling was concluded each year during November and was resumed the following spring for an approximate 4-week period during March and April to sample the fish prior to their seaward migration as smolts. The mean number of pre-smolts per acre during this spring sampling period is summarized in Table II.

Table II

The Mean Pre-Smolt Abundance in Numbers of Fish Per Acre by Lake Basin During the March to April Period 1961 to 1964 Inclusive.

Year	Basin 1	Basin 2	Basin 3	Basin 4	All Basins
1961	890	7430	960	100	2201
1962	350	890	540	30	453
1963	500	1640	1520	70	748
1964	420	1040	910	160	552
Means	540	2750	982	90	988

A shift in distribution occurred over the winter as evidenced by the low concentrations of pre-smolts in basin 4 and the relatively high concentrations in basin 2. The "all basin" data provides an estimate of the population density for the entire lake immediately prior to the annual, seaward smolt migration. The low abundance of pre-smolts in 1962 suggests an unusually high over-winter mortality during the 1961-62 winter. The cause of this relatively high mortality is as yet unknown.

Juvenile Sockeye Growth Rate

The growth rate of sockeye juveniles during the first year of lake residence is extremely slow. The fry take up residence in the offshore waters at an approximate size of 0.2 grams and by fall have attained a weight of only 1.0 grams. The slow growth during the first summer is partly compensated by an acceleration in growth during early spring, prior to seaward migration. This pattern of slow growth during the summer followed by a rapid spring growth prior to smolt transformation, apparently accounts for a distinctive scale pattern which distinguishes this stock of sockeye salmon from others in British Columbia.

In spite of the increased growth rate during the spring, the size at which Owikeno sockeye smolts go to sea is unusually small. Smolt samples were obtained in 1914, 1915 and 1916 by Gilbert and in 1956 by Foskett. Average fork lengths are given by Gilbert (1918) as 58.6 mm in 1914, 59.7 mm in 1915 and 59.6 mm in 1916. The mean size of 2000 smolts measured in 1956 was 61 mm in fork length and 2.0 grams in weight (Foskett, 1958). During the present study very little sampling of smolts was undertaken. The data that is available suggest that the mean smolt weight has varied during the past years from a low of approximately 1.8 grams in 1961 to a high of 2.4 grams in 1963.

In order to compare the growth of fish in different basins of the lake during each of the study years, the mean weight in grams of juveniles sampled in October has been listed in Table III.

Table III

The Mean October Weight of Juvenile Sockeye for Each Basin During the Period 1960 to 1963 Inclusive.

Year	Basin 1	Basin 2	Basin 3	Basin 4	All Basins
1960	0.8	0.7	0.6	0.6	0.8
1961	1.2	1.1	0.9	1.2	1.1
1962	1.0	1.2	0.8	1.0	1.0
1963	1.4	1.3	0.8	0.9	1.3
Means	1.1	1.1	0.8	0.9	1.0

The weight of juvenile sockeye has varied considerably over the study period. In 1960, the weight was the lowest of the four study years, and in 1963, it was the highest. The growth rate of sockeye juveniles in basins 3 and 4 was generally lower than in basins 1 and 2.

Examination of the growth rate and relative abundance of young sockeye in the various lake basins during the four-year period 1960-1963 suggested that a relationship existed between growth rate and population density. In Figure 2 the mean October weight of juveniles in the various basins of Owikeno Lake over the four-year period has been plotted against the population density occurring at that time. Data from basins 3 and 4 which comprise less than 8 percent of the total lake area, have been averaged and are represented by circled symbols. The data from basins 3 and 4 lie below an apparent lineal relationship which exists for the remainder of the lake. Large populations of stickleback are present in these uppermost basins, whereas stickleback are much less abundant in the large, lowermost basins. It is possible, therefore, that large populations of stickleback may depress the growth rate of sockeye juveniles in these uppermost basins.

The corresponding data for basins 1 and 2, as shown in Figure 2, strongly indicate that intraspecific competition plays a dominant role in controlling the growth rate of the young salmon in Owikeno Lake. An inverse relationship exists between population density and growth rate.

Juvenile Sockeye Survival

An estimate of summer mortality rate was obtained by calculating a series of regressions of catch per unit of effort against time. Logarithmic transformation was used to obtain a more symmetrical distribution from the skewed tow-net catch data. The unit of time was one day and the assumption was made that catchability and mortality rate remained constant during the sampling period. The regression coefficient indicates the rate at which the catch is changing with time and therefore provides an estimate of the survival over the sampling period. The percent summer survival over a 100 day period for each basin and for each year is tabulated in Table IV.

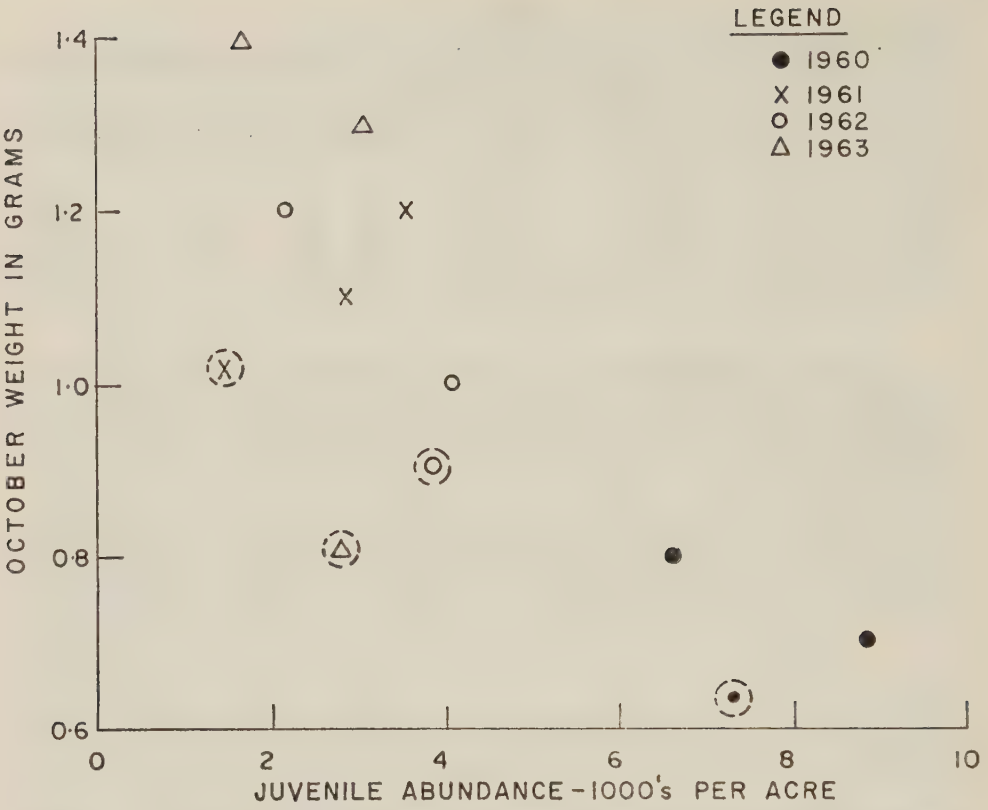

FIGURE 2. *A comparison of the abundance of juvenile sockeye salmon in terms of thousands of fish per acre with the October weight in grams for the years 1960 to 1963 inclusive.*

Table IV

The Summer Survival in Percent During the 100-Day Sampling Period for Each Basin During the Period 1960 to 1963 Inclusive.

Year	Basin 1	Basin 2	Basin 3	Basin 4	All Basins
1960	30	17	6	25	26
1961	40	32	9	79	39
1962	29	66	2	39	33
1963	96	63	17	100	82
Means	49	44	9	61	45

The apparent low survival rates in basin 3 suggest either that catchability did not remain constant over the sampling period in this region of the lake or that a summer movement of fish occurred away from this basin. In 1963 a trap was installed in the third narrows situated between basins 3 and 4, to determine whether extensive fish movements occurred between these two basins. Catch data from the trap showed that during the summer of 1963 considerable numbers of juvenile

sockeye salmon moved out of basin 3 and into basin 4. The survival data from these two basins, therefore, have been grouped together and an average figure has been used in the following section of this report to represent the survival rates for this region of the lake. The "all basin" data has been weighted for the relative number of fish present in each basin.

An examination of the survival estimates and the growth rate of the juveniles concerned, showed that a rather well-defined relationship existed. In Figure 3 the October weight of juvenile sockeye is plotted against the corresponding survival estimates. The data indicate that a positive correlation exists between summer survival and growth rate.

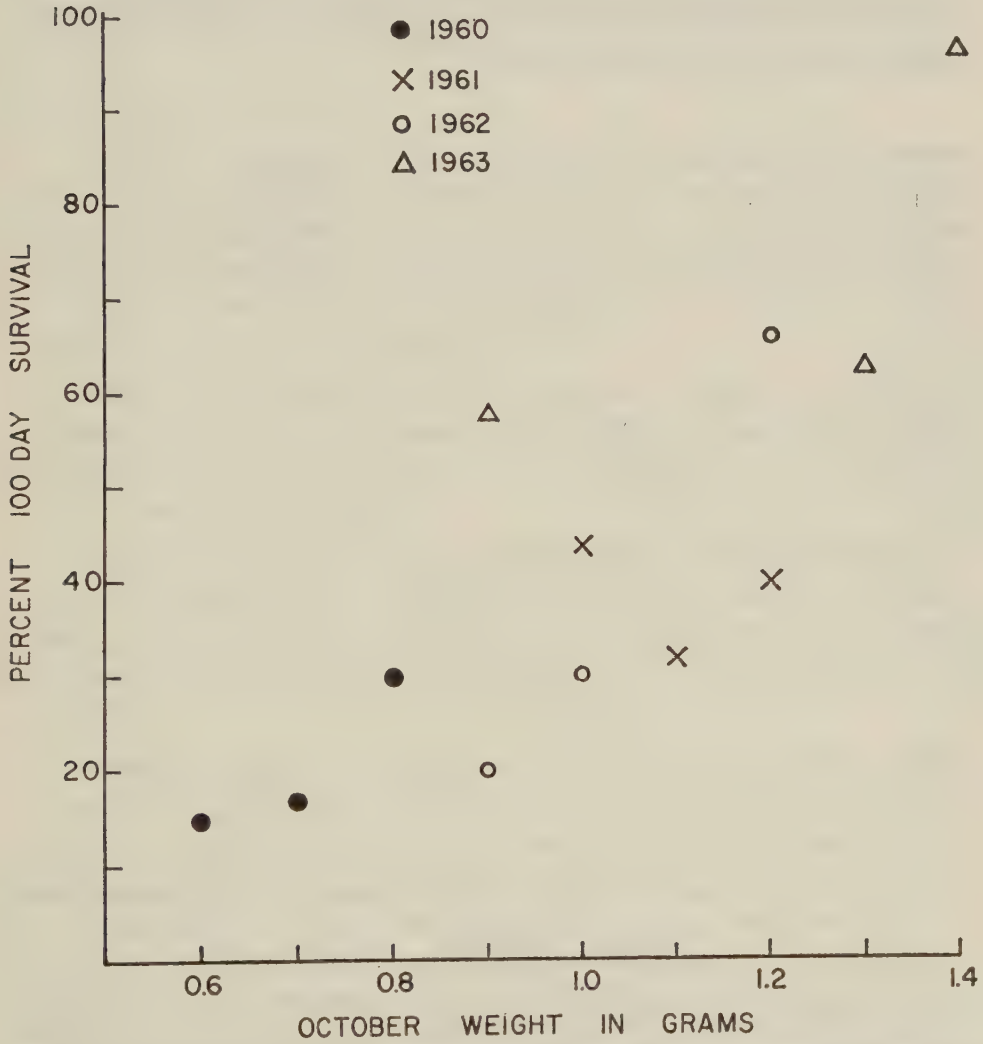

FIGURE 3. *A comparison of the October weight of juvenile sockeye salmon in grams with the percentage 100-day survival measurement for the years 1960 to 1963 inclusive.*

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Since an apparent relationship exists between growth rate and both summer survival and population density the possibility that a correlation exists between survival and population density was explored. Once again data from basins 3 and 4 were combined and examined along with data representing basins 1 and 2. Analysis of these data from the four study years indicates that an inverse correlation does in fact exist and the relationship is depicted graphically in Figure 4. The figure suggests that at population densities of 2000 fish per acre, survival can be quite high. Survival appears to fall swiftly as the population density increases to 4000 fish per acre, then declines gradually as the population density increases to 9000 fish per acre. Although the exact shape of this curve is difficult to establish from these data, it indicates that summer survival is low when population densities exceed 4000 fish per acre. The rate of survival during this summer period, therefore, is determined to a large extent by a density dependent factor.

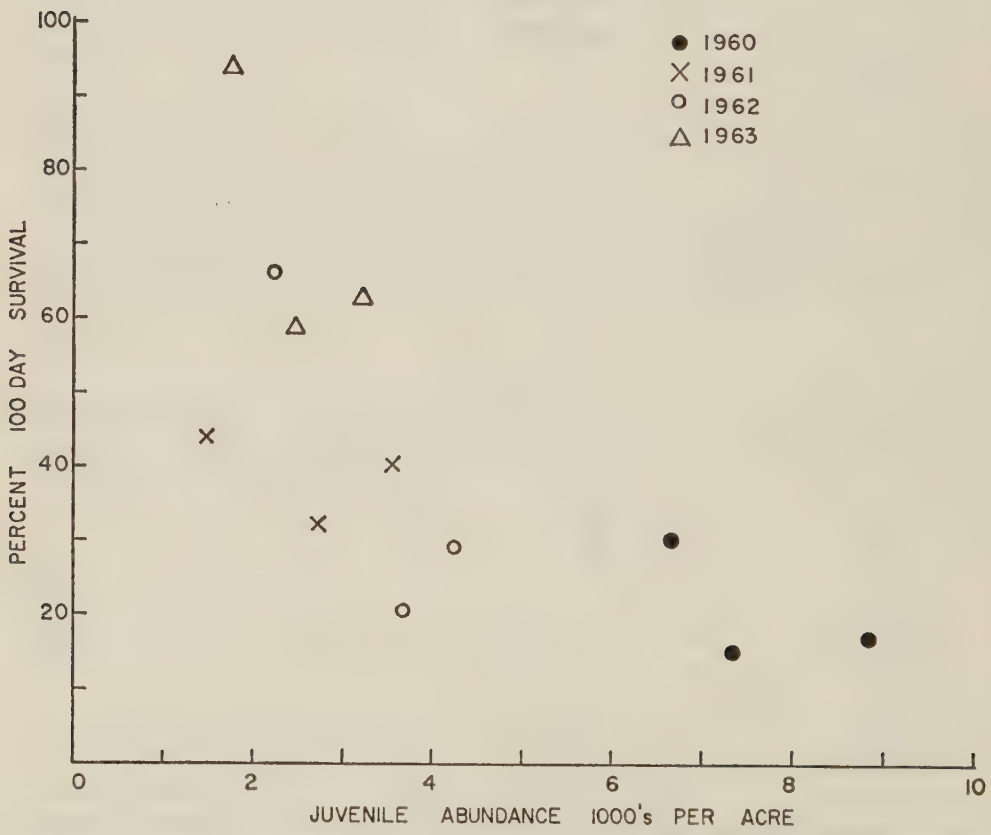

FIGURE 4. *A comparison of the juvenile sockeye salmon abundance in terms of 1,000's of fish per acre with the percent 100-day survival measurement for the years 1960 to 1963 inclusive.*

The existence of intraspecific competition would indicate that the capacity of the lake nursery plays a dominant role in controlling the maximum population level of the Rivers Inlet sockeye salmon stock.

Effects of Lake Environment on Juvenile Sockeye

The existence of intraspecific competition would indicate that the capacity of the lake nursery probably controls the upper limits of production of the Rivers Inlet sockeye salmon stock. The density dependent nature of the growth and survival relationships suggest that food, and/or space, act as a population control limiting smolt production from Owikeno Lake. In order to describe the environment and document long and short-term changes in the lake, several limnological observations were made during the course of this study.

Surface Water Temperature

Donaldson and Foster (1941) demonstrated by controlled experiments that water temperature constituted a controlling factor on growth of young sockeye salmon. Their results indicated that growth was very slow below 40°F, increased rapidly with increase in temperature until a plateau of favourable growth conditions was reached extending from 45° to 68°F. Above 68°F the growth rate declined rapidly, and above 70°F a weight loss occurred.

Foerster (1937) showed that the annual migration of smolts from Cultus Lake terminated as the surface temperature rose to 63.5°F. He suggested that rising temperatures created a thermal barrier in the epilimnion through which sockeye fingerlings were reluctant to pass.

Burgner (1962) showed a direct relationship between spring temperatures and growth of pre-migratory sockeye fingerlings in the Wood River Lakes in Alaska. He warns, however, that his should not be regarded as proof of direct cause and effect, but rather as a measure of general differences in environment caused by climatic conditions.

In Owikeno Lake, low summer air temperature, glacial runoff and strong winds produce a relatively cold and deep epilimnion. The surface waters are seldom if ever too warm for efficient growth of young sockeye. Temperature within the range found optimum by Donaldson and Foster (op. cit.) existed in the surface waters from May to October. An examination of surface temperatures during springtime suggested that water temperature does not appear to influence the timing of the annual seaward migration of smolts. The mean monthly surface temperature for basins 1 and 2 is plotted for the 4-year sampling period in Figure 5A. Similar data for basins 3 and 4 are depicted in Figure 6A.

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Water Transparency

Light penetration into the waters of Owikeno Lake is restricted by large quantities of suspended glacial silt. The transparency, therefore, follows a seasonal cycle of low secchi disc recordings during the summer when glacial run-off is high, and relatively high secchi disc readings in the winter when glacial run-off is low. The restriction of light to only the top few feet of the extensive epilimnion must drastically reduce the production of phytoplankton, a portion of which serves as food for zooplankton, which in turn is the main food of young sockeye salmon. On the basis of these facts, water transparency must be considered as a basic factor in the production of juvenile sockeye. In opposition to this negative effect, however, the low transparency may constitute a positive factor in juvenile sockeye production in that the environment is one in which susceptibility to predation may be low. The mean monthly secchi disc recordings for basins 1 and 2 are graphed in Figure 5B, and for basins 3 and 4 in Figure 6B.

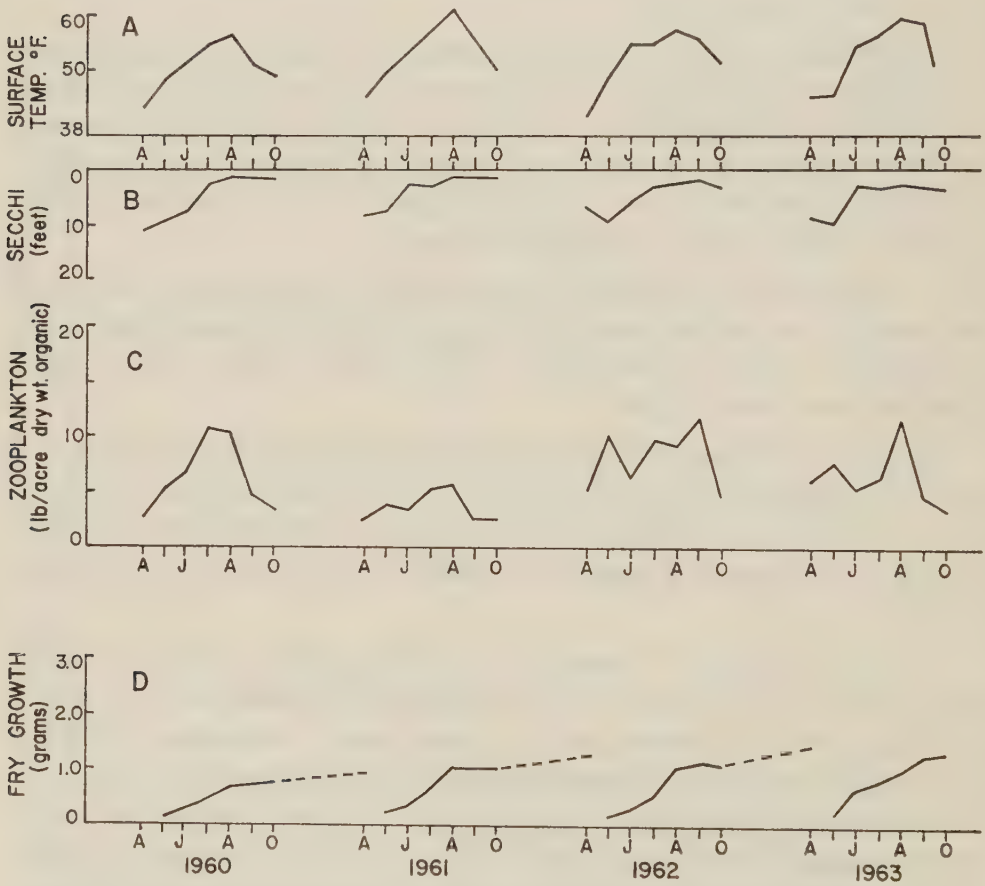

FIGURE 5. *The mean monthly surface temperature; the mean monthly secchi disc recordings; the mean monthly dry weight of organic matter; and the mean monthly weight of sockeye juveniles for basins 1 and 2 during the period April to October and for the years 1960 to 1963 inclusive.*

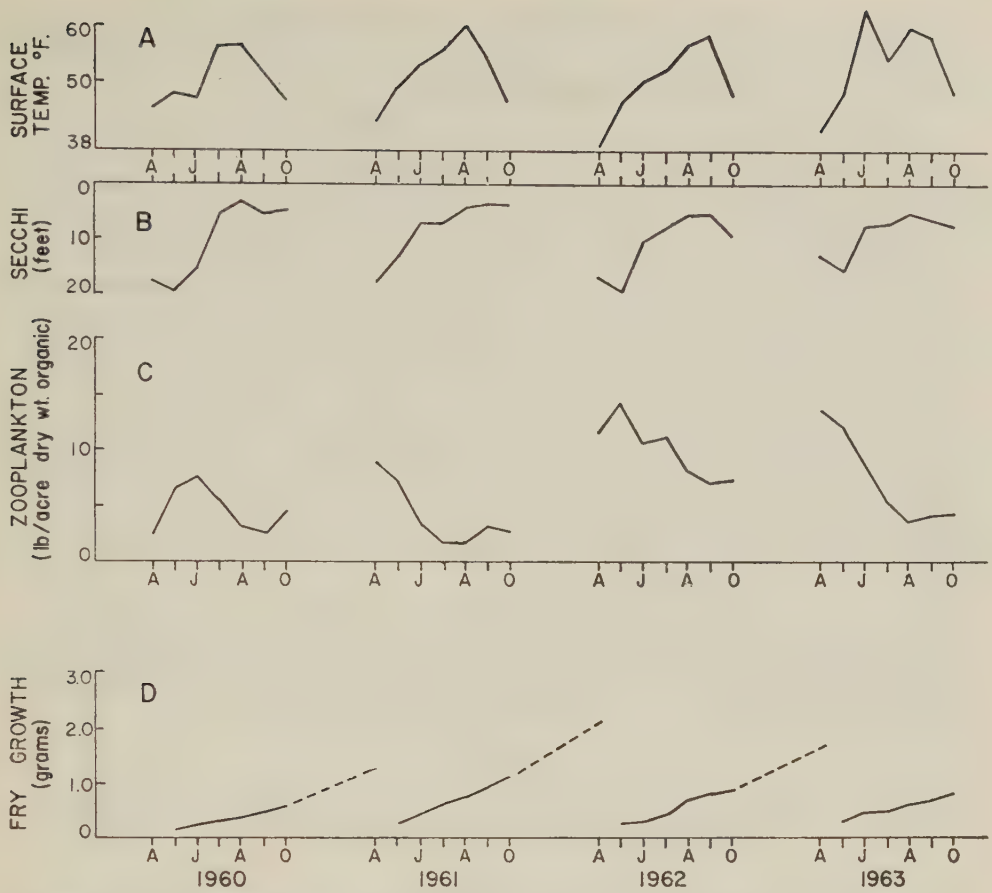

FIGURE 6. *The mean monthly surface temperature; the mean monthly secchi disc recordings; the mean monthly dry weight of organic matter; and the mean monthly weight of sockeye juveniles for basins 3 and 4 during the period April to October and for the years 1960 to 1963 inclusive.*

Zooplankton Abundance

Periodic examinations of sockeye juvenile stomachs caught in the tow-nets confirmed that zooplankton was the most important food consumed. This is of particular importance in that fluctuations in availability of zooplankton could influence the growth rate and hence survival of the lake sockeye. In order to examine seasonal as well as annual fluctuations in zooplankton standing crop over the four study years, the mean monthly dry weight of organic matter for basins 1 and 2 is graphed in Figure 5C. Similar data for basins 3 and 4 are shown in Figure 6C.

In basins 1 and 2 zooplankton abundance is low during early spring, peaks during the summer and then falls to very low levels during the fall. In basins 3 and 4 zooplankton is most abundant during the spring, decreases to a summer low during August and remains low during the fall. The early spring maxima during 1961,

1962 and 1963 suggest that winter populations were relatively high during this period. This is in contrast with basins 1 and 2, where winter zooplankton populations appear to be quite low.

Significant differences in the qualitative aspects of the zooplankton between the upper and lower basins occurred. Numerical counts of the various taxonomic groups were made during 1960 and 1961. This analysis indicated that the rotifers *Kellicottia longispina, Asplancha priodonta* and *Filinia longiseta* were abundant in the upper basins, but were rare or absent in the lower basins. Similarly, the cladoceran, *Daphnia pulex* was abundant in the upper basin, very rare in basin 2 and absent from basin 1. Ricker (1937) found that *Daphnia* was one of the most common plankton animals found in young sockeye stomachs from Cultus Lake. The rotifers mentioned, however, are probably of little importance as sockeye salmon food in Owikeno Lake. The most abundant zooplankter throughout the whole lake was the copepod *Diaptomus sp.* These animals were two to three times as abundant as another copepod, (*Cyclops vernalis*), found throughout the lake. Based on availability, copepods appeared to be the most important plankton food for juvenile sockeye in most of Owikeno Lake, except possibly in basin 4, where *Daphnia* was equally important.

In order to examine the annual difference in zooplankton standing crops, the mean April to October dry weight of organic matter expressed in pounds per acre for each basin of Owkeno Lake is tabulated in Table V. The "all basins" data have been weighted for the respective area of each basin.

Table V

The Mean April to October Dry Weight of Organic Matter Expressed in Pounds Per Acre for Each Basin During the Period 1960 to 1963 Inclusive.

Year	Basin 1	Basin 2	Basin 3	Basin 4	All Basins
1960	4.5	6.0	3.1	6.7	5.0
1961	3.5	3.7	2.0	6.1	3.7
1962	7.5	7.4	7.7	12.3	8.2
1963	6.1	6.6	4.2	10.5	6.3
Means	5.4	5.9	4.3	8.9	5.8

The plankton data in Table V represent extremely low zooplankton populations which are characteristic of deep, cold oligotrophic lakes. The standing crop in basin 4 was higher during all 4 years than that of the remainder of the lake, while in 3 of the 4 years, basin 3 exhibited the lowest standing crop. From year to year, the quantity of zooplankton in all basins varied similarly. This fact suggests that the zooplankton are reacting to a common climatic condition.

As mentioned previously, the presence of glacial silt in Owikeno Lake is a limiting factor governing phytoplankton production and hence indirectly, zooplankton production. Although more data is required before the relationship between transparency and zooplankton standing crop can be defined, it appears likely that the relative clarity of the lake may play an important role in governing the zooplankton production of Owikeno Lake.

No significant relationship between juvenile sockeye growth or survival and zooplankton abundance was found. This is surprising, especially in the light of the strong evidence indicating that intraspecific competition occurred among sockeye juveniles during the study period.

Stickleback Abundance and Distribution

The main competitor of sockeye juveniles for the rather meagre zooplankton food supply in Owikeno Lake appears to be the three-spined stickleback (*Gasterosteus aculeatus*). Large numbers of these fish were caught in certain regions of the lake at the same time sockeye juveniles were being sampled. Although catches of stickleback fry were made throughout the sampling period, catches were much higher in the spring than during the remainder of the season. In some years a second increase in abundance was noted in the early fall. The life span of Owikeno stickleback appears brief and probably averages about one year. On the basis of the abundance of adult stickleback caught throughout the year, it would appear that very few individuals spawn more than once. The mean stickleback abundance in fish per acre during the period April to October for the various regions of the lake is listed in Table VI

Stickleback were not evenly distributed throughout the lake; and in basin 1 a relatively low abundance was recorded each year. Greenbank and Nelson (1959) give a detailed description of the life history of the three-spined stickleback in Karluk and Bare Lakes, Alaska, where they describe stickleback spawning in shoal waters around the shores of these lakes. In Owikeno Lake suitable spawning area for this species is restricted largely to the upper two basins and this probably accounts for the uneven distribution of stickleback in Owikeno Lake.

Table VI

The Mean April to October Abundance of Stickleback (*Gasterosteus aculeatus*) in Numbers of Fish Per Acre for Each Basin During the Period 1960 to 1964 Inclusive.

Year	Basin 1	Basin 2	Basin 3	Basin 4	All Basins
1960	52	2670	4630	7310	1059
1961	40	2570	2040	3340	770
1962	41	550	735	1710	242
1963	19	485	883	2490	251
Means	38	1568	2070	3712	580

The "all basin" data has been weighted for the relative area of each basin and represents a measure of the annual abundance during the four study years. In 1960 the stickleback were over three times as abundant as in 1962 or 1963. If stickleback compete with juvenile sockeye for food, their relative abundance in the lake would influence the production of salmon from regions where stickleback abound. Some suggestion that this does occur was provided by the fact that the growth rate of sockeye juveniles was depressed in basins 3 and 4 where the highest density of stickleback was found (Figure 2).

Discussion

These data form the beginning of a body of scientific knowledge currently being assembled on the production dynamics of the Owikeno Lake sockeye populations. This presentation deals with the first 4 years of a study which is long term in nature and which constitutes the initial stage of a proposed large scale biological investigation. Although the present studies have only been pursued over a relatively short period of time, they have already provided a basic understanding of the factors affecting production of juvenile sockeye salmon in Owikeno Lake.

The density dependent nature of growth and survival of sockeye juveniles during their lacustrine life history suggests that the lake environment, rather than availability of spawning area limits the total production of the Rivers Inlet stock. Detailed information on the distribution and size of the adult escapement is required to fully understand the inter-relationships involved in determining optimum escapement levels. The magnitude of the runs, the time interval between migration up the Wannock River and subsequent spawning, the glacial nature of the lake and major tributary streams, have all presented difficulties in attaining an accurate measure of the escapement. The next phase of the study should be directed at overcoming this problem.

The morphometry, low temperature, high turbidity, low standing crop of zooplankton and the extremely slow growth rate of lake rearing sockeye salmon, all indicate low basic productivity in Owikeno Lake. Of the physical conditions of the lake, water transparency appears to exert the greatest effect on lake productivity. Phytoplankton cells transported throughout the deep epilimnion are exposed to light conditions suitable for photosynthesis for a relatively short duration. Since zooplankton depend upon phytoplankton for food, water transparency would indirectly affect the production of zooplankton.

No apparent relationship exists between zooplankton standing crop and juvenile sockeye abundance. Ricker (1937) found an inverse correlation between zooplankton abundance and population size of sockeye salmon juveniles in Cultus Lake, British Columbia. A similar inverse correlation between sockeye abundance and zooplankton standing crop in different regions of Babine Lake has occurred, Johnson (1964). In both instances the reduction of zooplankton was assumed to be the result of extensive grazing by large populations of juvenile sockeye, and hence indirect evidence that intra-specific competition for food existed. The fact that no correlation was found between zooplankton standing crop and sockeye abundance in Owikeno Lake, in spite of the density dependent nature of growth and survival, suggests that there is an effect of competition which is expressed independently of absolute food abundance.

If, in Owikeno Lake, only a relatively small portion of the total zooplankton crop was utilized by sockeye juveniles, then the effect of grazing on the total plankton crop would be minimal. At the same time, intraspecific competition for the portion utilized would be intense. The opaqueness of Owikeno Lake could limit the effective grazing zone for juvenile sockeye to the top few feet of epilimnion. Perhaps zooplankton sampling restricted to this zone would reveal the effect of grazing on the zooplankton present there. The possibility exists, however, that the

intraspecific competition in Owikeno Lake is not directly for food, even though the final result of this competition is retarded growth rate. Whatever the mechanism involved, the density dependent nature of growth and survival undoubtedly influences the production dynamics of the Owikeno Lake sockeye populations.

Acknowledgments

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Table I

Summary of Regression Analyses for 1960, 1961, 1962 and 1963.
Logarithm of Catch Per Unit Effort on Time, the Unit of Time = 1 day.

1960

Station	N	b	$\overline{X}$ (Mean Date)	$\overline{Y}$ (Mean Log)	Antilog $\overline{Y}$ (Geometric Mean)	Syx	95% Confidence limits of $\overline{Y}$	Antilog of 95% Confidence limits of $\overline{Y}$	Confidence Range	Confidence Range as % of Mean
I	22	−.00466	Sept. 12	2.1699	148	.6703	1.872 2.468	74 294	220	149%
II	17	−.00603	Aug. 28	3.0754	1190	.4217	2.857 3.293	719 1964	1245	105%
III	26	−.00758	Sept. 4	2.9486	888	.2746	2.838 3.060	688 1148	460	52%
IV	8	−.01209	Aug. 29	2.9186	829	.1093	2.824 3.013	667 1030	363	44%
V	11	−.00661	Aug. 31	2.7911	618	.3717	2.538 3.044	345 1107	762	123%

1961

I	13	−.00802	Aug. 26	1.9557	90	.4501	1.681 2.230	48 170	122	136%
II	16	−.00204	Sept. 1	2.8050	638	.2017	2.697 2.913	498 818	320	50%
III	24	−.00493	Sept. 19	2.4593	288	.2020	2.374 2.545	237 351	114	40%
IV	14	−.01035	Aug. 28	1.9881	97	.3531	1.783 2.194	61 156	95	98%
V	16	−.00100	Sept. 8	2.2985	199	.2990	2.138 2.459	137 288	151	76%

1962

I	15	−.00516	Sept.	3	2.1205	132	.4400	1.8751 2.3659	75 232	157	109%
II	15	−.00555	Sept.	1	2.8380	689	.2623	2.6918 2.9842	492 964	472	68%
III	18	−.00184	Sept.	1	2.3450	221	.1649	2.2626 2.4274	183 268	85	38%
IV	17	−.01738	Aug.	26	2.6537	451	.2621	2.5182 2.7892	330 615	285	63%
V	17	−.00406	Aug.	24	2.4721	297	.2577	2.3389 2.6053	218 403	185	62%

1963

I	15	+.000102	Sept.	1	2.2164	165	.3801	2.0045 2.4283	101 268	167	101%
II	16	—.000324	Aug.	28	2.3494	224	.3313	2.1722 2.5266	149 336	187	84%
III	16	−.002211	Aug.	28	2.5113	326	.2254	2.3906 2.6320	246 429	183	56%
IV	16	−.007757	Aug.	29	2.4686	294	.3732	2.2690 2.6682	186 466	280	95%
V	15	+.0001103	Aug.	30	2.3500	224	.4749	2.0851 2.6149	122 412	290	129%

First winter mortality of Atlantic salmon parr in the hatchery

by
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Abstract

The dependence of first winter mortality in Atlantic salmon in the hatchery on mean fish size and on crowding was studied on routine data for three winter seasons. Within the year-class mortality is largely determined by mean individual size of fish in the lots, whereas crowding has less or no significance within the ranges investigated. Between year-classes no such dependence was found. Apparently absolute size in itself does not necessarily determine first winter mortality, but size position within the group (year-class). A dual nature of size as factor of ecological importance is suggested.

Introduction

Salmon conservation in Sweden rests upon the planting of smolt-sized hatchery 2-year parr in spring (Carlin 1960, Lindroth 1963). This means two winters in the hatchery. It is generally recognized that the smaller one-summer-old parr suffer a heavier loss during the first winter in the hatchery than the larger ones and for this reason the salmon culturist has tried to raise the fish to the largest possible size in the first summer in order, among other purposes, to minimize winter losses.

This working hypothesis has been tested on the wintering stocks of salmon parr in Bergeforsen's salmon rearing station.

Material

The material consists of routine data on wintering salmon parr (1960/61, 1961/62 and 1962/63) from the Bergeforsen salmon rearing station. They were held in concrete troughs, 5.6 m^2, with circulating water. The mortality (daily picking of dead fish) is given for the period from stocking the troughs in October to December 31. Before stocking, the fish was graded.

Table I

Survey of the Material.

Year-class	1960	1961	1962
Total number of fish	553,000	481,000	610,000
Number of lots (troughs)	43	47	47
Mean number of fish/trough	12,870	10,240	12,980
Mean weight of fish/trough (kg)	30.5	35.7	26.5
Mean weight of individuals (g)	2.4	3.5	2.0
Mean rate of mortality (%)	6.2	2.1	2.1
Mean length of period (days)	88	86	75

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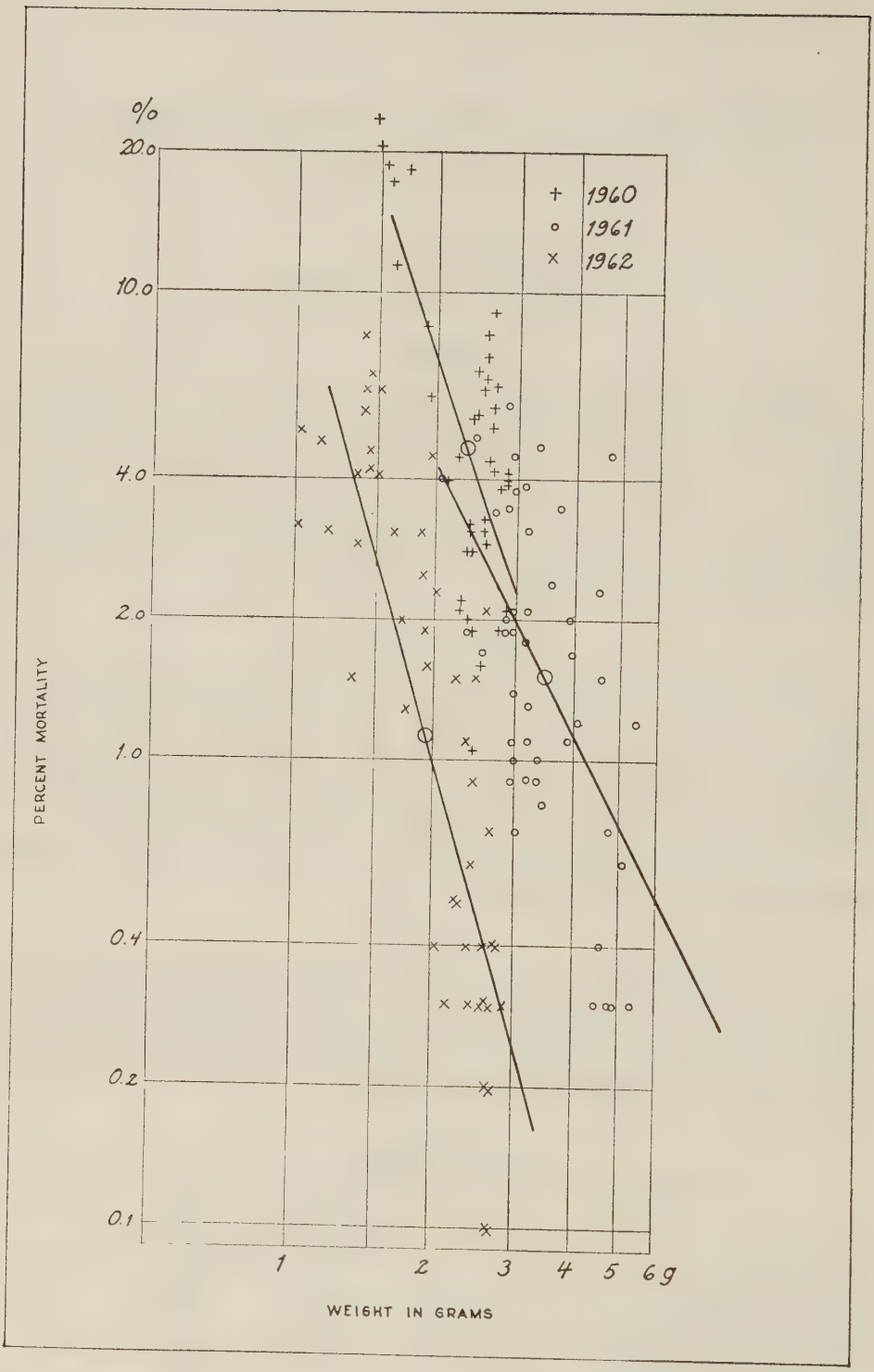

Fig. 1 Regression of mortality (% from time of stocking to December 31) on mean individual weight (g at stocking) in lots of hatchery underyearling Atlantic salmon of three year-classes.

Results

a. Winter mortality within a year-class

Within each year-class there exists a mathematical relationship between degree of crowding and mortality, as well as between mean individual size of the parr in a trough and mortality (Fig. 1). However, as crowding and individual weight are interdependent (small fish are kept more crowded than larger fish in order to maintain roughly the same weight load in the troughs) the relationships have been studied by means of partial regression calculation.

Table II

Relation Between Crowding (X_1, in 1,000's per trough), Mean Individual Size of Parr in a Trough (X_2, in g), and Mortality (Y, in %) as Expressed by Partial Cœfficients of Logarithms of Data.

Year-class	R	$r_{y1\cdot 2}$	$r_{y2\cdot 1}$	$b_{y1\cdot 2}$	$b_{y2\cdot 1}$
1960	0.69	−0.27	−0.55	−1.80	−4.27
1961	0.56	0.04	−0.31	0.21	−1.78
1962	0.82	−0.32	−0.80	−1.62	−3.87

The dependence of mortality on fish size is high after elimination of the influence of crowding. Crowding, by comparison, has much less if any significance, and it seems difficult to explain the nature of the relationships indicated in year-classes 1960 and 1962 where mortality decreases at increasing number of fish in the trough.

For the moment it seems safe to conclude that, whereas mean individual size of fish in the lot within a year-class largely determines the mortality rate, no such influence is exerted by number of fish—or, consequently, by the total trough load—within the range investigated.

b. Winter mortality between year-classes

The data for the year-classes 1960 and 1961 and the results from the section "a" above would lend support to the general belief that smaller fish give higher winter mortality. However the high mortality expected for the year-class 1962, very small fish on account of a cold summer, failed to appear. Mortality in 1962 (2.1%) was equal to that of the large parr in 1961 (2.1%) or not very much higher (2.4%) if corrected for the shorter period of holding by direct proportion (75 days as against 86 days). It was far below the figure for 1960 (6.2%) for parr of comparable size and crowding.

Apparently, absolute size in itself does not necessarily determine mortality.

Discussion

Growth, i.e. size at the same age, is genetically and environmentally governed.

In identical environment, attained size can be said to express inherent differences influencing growth rate. In the fairly similar environmental conditions affecting one salmon year-class group in the standardized operations of a big

hatchery, growth differences are in part likely to indicate differences in viability, small size indicating inferiority in one or several respects. Subjected to adverse conditions, small specimens would be the most liable to succumb.

In dissimilar environment attained size can not be regarded as an expression for inherent capacities. The different sets of environmental conditions (e.g. temperature, food) affecting successive year-classes give rise to differences in growth which do not correspond to differences in viability. The smaller fish *within* a year-class group is apparently inferior to the "average fish" in this same year-class but, compared *between* year-classes, a smaller mean size does not necessarily indicate inferiority in general viability.

The lack of a relationship between *absolute* size of one summer old hatchery salmon parr and winter mortality, found in the present investigation, is in agreement with the above theoretical considerations as in the relation between *relative* size within year-class and mortality.

Further, based on this small study it is suggested that a dual nature of size as reactor (property of the organism determining the response to ecological factors) should receive attention: (*a*) size in itself, absolute size, directly related to success of individuals, (*b*) size position within the group, relative size, as indication of general viability.[1]

Acknowledgments

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[1] Carlin informs (personal communication) that this way of reasoning is true in respect of planted hatchery salmon smolts: the influence of smolt size on return to the fishery is more pronounced within family groups (*see* Carlin 1963, Fig. 6) than between families, the general picture being essentially the same as diagram, Fig. 1.

Effects of a Diet of Raw Smelt on Lake Trout[1]

by

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Introduction

When included in the diet, raw fish or raw fish products have caused thiamin (Vitamin B1) deficiency in foxes, where the disease is known as Chastek paralysis, (Green and Evans, 1940; Green, Carlson and Evans, 1942), in chicks (Spitzer, et al., 1941) and in fish (Wolf, 1942; Harrington, 1954). Even in humans thiamin excretion has been shown to be reduced by half with diets containing raw clams (Melnick, et al., 1945). The causative factor in raw fish has been identified as a heat labile enzyme, thiaminase (Krampitz and Woolley, 1944; Deolalker and Sohonie, 1954). The symptoms of thiamin deficiency in fish are similar to those in other animals and are described by several workers (e.g. Woodbury, 1942; Wolf, 1942; Harrington, 1954) to include first a cessation of feeding, loss of equilibrium and other nervous disorders, extreme sensitivity to external stimuli and finally complete paralysis and death. During the period when feeding has stopped, fish seem more unable than unwilling to feed, for they do take food into the mouth, but then reject it.

In fish thiaminase activity has been found in quantity in the viscera and in the combined head, fins, skin and scales, but it appears to be absent in somatic muscle (Green, Carlson and Evans, 1942; Suomalainen and Pihlgren, 1955). Thiaminase activity has been found among many species but appears to be more prevalent in fresh water than marine fishes, particularly fresh water Cyprinids (Deutsch and Hasler, 1943; Lieck and Agren, 1944; Suomalainen and Pihlgren, 1955).

Smelt have not always been found to possess the enzyme. Lieck and Agren (1944) could not find a significant amount of thiaminase activity in a smelt, *Osmerus eperlanus* (L.). Wolf (1942) found no evidence of thiamin destruction by including the American smelt, *Osmerus mordax* (Mitchill) in the diet of brook trout, *Salvelinus fontinalis* (Mitchill), fingerlings. On the other hand Deutsch and Hasler (1943) reported thiaminase to be present in American smelt, and further, they state that Deutsch and Ott (1942) proved by chick and thiochrome assays that smelt do contain the destructive enzyme. More recently Gnaedinger (1964) found thiaminase activity in American smelt.

The reported presence of thiaminase in American smelt and the fact that lake trout, *Salvelinus namaycush* (Walbaum) feed heavily on smelt when they are available has led to the idea that smelt have been responsible in some measure for the decline of some lake trout stocks (cf. Owen Sound (Ontario) Sun-Times, March 8, 1963, p. 3). The relationship is not quite so simple as implied however, for lake

[1] Contribution No. 65-24 from the Ontario Department of Lands and Forests, Research Branch, Maple, Ontario.

water contains dissolved thiamin (Hutchinson, 1957). It would seem to be possible, therefore, for lake trout to feed on smelt containing thiaminase, but not to suffer thiamin deficiency.

In order to investigate this possibility an experiment in which smelt was fed to lake trout was carried out in 1964 at the South Bay Fisheries Research Station, Lake Huron.

Materials and Methods

Lake trout were held indoors in four adjacent tanks each 107 by 52 by 49 cm containing about 140 litres (30 Imp gal) of water. Lake water from South Bay was pumped to two of the tanks (numbers 1 and 2) from an intake pipe approximately two meters below the water surface. The other two tanks (numbers 3 and 4) received well water. Hatchery reared, 2-year old lake trout from Lake Simcoe stock were transferred to South Bay from the Laboratory for Experimental Limnology[1] at Maple, Ontario, on February 21.

In the following month, during adjustments of water supplies 11 trout died, so that from April 1 to the end of the experiment on July 9, nine trout were held in each of the four tanks.

The trout in two of the tanks, numbers 1 and 3 receiving lake and well water respectively, were fed a test diet of raw smelt while those in tanks 2 and 4, also receiving lake and well water respectively, were given a control diet consisting mainly of trout pellets and raw pork liver. The feeding schedule is summarized in Table 1A, where it can be seen that all tanks received the same diet up to mid April and that thereafter the test and control diets were fed.

Most of the smelt used were caught on April 27 in Lake Manitou, an inland lake in Manitoulin Island. Others were caught in tributary streams of South Bay earlier in April and in pound nets set in the bay in June. The Lake Manitou smelt catch was held alive in a separate tank until May 9. Before that date, some of the smelt, which were about 10 cm (4 in) in length were removed, put in plastic bags and frozen. The remainder were fed to the trout fresh daily. After May 9 the trout received mostly frozen smelt with occasional supplements of fresh smelt caught in the South Bay pound nets.

[1] Administered jointly by the Ontario Department of Lands and Forests and the University of Toronto.

Table 1.

Summarized Conditions Concerning Diet, Temperature, and Dissolved Oxygen in Tanks Containing Lake Trout. Tanks 1 and 2 Received Lake Water; Tanks 3 and 4 Received Well Water.

A. Summarized Feeding Schedule of Lake Trout

Date	*Tanks 1 & 3*	*Tanks 2 & 4*
February 21 to April 15	Trout pellets, minnows	Trout pellets, minnows
April 16, 21, 23, 25	Smelt	Trout pellets
April 27 to June 10 daily	Smelt (fresh or frozen)	Trout pellets supplemented occasionally with bread, canned catfood, frozen pork liver
June 11 to July 9 daily	Smelt (fresh or frozen)	Frozen pork liver supplemented with trout pellets

B. Temperature °C

	Lake Water		*Well Water* (individual observations)	
April 22-30	Mean	8.8	Apr. 1	7.8
	Max.	11.1	21	7.8
	Min.	6.1	May 7	8.4
May	Mean	12.4	27	8.9
	Max.	14.7	June 6	9.4
	Min.	10.5	10	9.4
June	Mean	15.9	20	10.0
	Max.	22.0	29	11.1
	Min.	13.6	July 1	10.6
July 1-10	Mean	19.9	3	10.6
	Max.	24.2	6	11.6
	Min.	15.0		

C. Dissolved oxygen p.p.m.

	Lake Water	*Well Water*
May 7	11	6
8	11	5
19	10	8
June 10	10	6
20	10	6

Usually six smelt, but sometimes fewer if some were large, were fed to the trout daily. The smelt were cut into small bits and the pieces dropped into tanks 1 and 3. The procedure was the same whether fresh or frozen smelt were fed. On some days pork liver, which had been frozen in half pound lots, was thawed and half of it fed to the trout in tanks 2 and 4 that day and the rest the next day. The liver too was diced and half the pieces dropped into each tank. On days that pellets were fed, each of the tanks 2 and 4 received about 25 to 30 grams.

Surface water temperatures are recorded continuously at the dock of the South Bay Fisheries Research Station. The temperature recorder is located within about 50 meters of the lake water intake. Mean, maximal and minimal lake water temperatures at four p.m., generally the time of the daily maximum, for various periods of time are shown in Table 1B. Well water temperatures measured in the tanks on various days are also shown there. These data are presented in order to show that throughout the period mid April to July 9, the time during which the test diet was fed, the lake water was consistently warmer than the well water.

The oxygen concentration of the water in the tanks as determined by the Winkler method on five occasions is shown in Table 1C. Single samples were taken on May 7, but on the other four dates that oxygen measurements were made, duplicate samples were taken from each tank, and in every case close agreement in oxygen concentration between the two replicates was obtained. On May 14 a plywood baffle 61 cm long and 15 cm wide (2 feet by 6 in) was installed over each of tanks 3 and 4. From then on the well water entering these tanks was allowed to flow over the baffles in order to aerate it.

The work of Swift (1963), Hermann, et al. (1962) and others has indicated that the oxygen levels indicated in Table 1C are not low enough to restrict growth of salmonids. Hence, it may be assumed that the difference in oxygen content of the two water supplies in this experiment had little effect on the results obtained.

Results

During this experiment there were no mortalities in any tank, and symptoms occurring in the latter stages of thiamin deficiency did not appear. Early symptoms of the disease were observed, and all occurred in tank 3. It may be seen in Table 1A that smelt was fed on April 16, 21, 23, 25, and from 27 on, daily. On the first day that smelt was fed, it was all eaten in both of tanks 1 and 3. Shortly after feeding on April 21, it was also observed that most of the food in all tanks was gone. When food was placed in the tanks two days later, there was some immediate feeding in all tanks, but it soon became apparent that the trout in tank 3 were not feeding as well as the others. On April 30 a fish in tank 3 was observed to pick up and then reject food. Thereafter feeding in tank 3 virtually ceased, and up to the end of the experiment smelt bits were removed from the tank every few days. From July 7 to the termination of the experiment on July 9, some of the trout in tank 3 were unable to maintain their equilibrium. Throughout the entire period the fish in tank 1 fed normally, all food being rapidly eaten.

It may also be noted in Table 1A that the fish in tanks 2 and 4 received mostly trout pellets with liver as a supplement up to June 10 and that thereafter liver was the main constituent of the diet. The trout apparently had little appetite for pellets. When pellets were placed in the tanks, those that were not immediately eaten, slowly disintegrated and became mixed with feces. It was not realized until June 10 that the trout were not feeding well on pellets. After that date (as well as before) the trout fed well on liver. It was apparent, however, particularly in June that those in tank 2 were feeding better than those in tank 4. Food disappeared more quickly in tank 2 and sometimes not all food was eaten in tank 4.

On June 4 and July 9 the trout were anesthetized with MS222, fork length was measured to the nearest millimeter and weight determined in grams. Condition factor (K_{FL}) was calculated by the formula $K_{FL}=Wt/Lt^3$ (cf. Lagler, 1956). All calculated condition factors were multiplied by 10,000 to convert them to whole numbers. Table 2 shows lengths and condition factors of all trout on June 4 and July 9 and the changes that occurred between the two dates.

It was observed during the experiment that in some tanks at least one of the small fish appeared to be dominated by all the others. Such a fish would remain at the back of a tank when food was dropped into the front of it, and either would not feed at all or would make only one pass at the bits of food. It seems reasonable that the condition of such a fish would be the poorest in a tank; furthermore, its condition would be attributable to the behaviour of the fish, not to their diet. Condition factors, of course, were calculated to compare fish receiving different diets. Therefore, the fish in each tank with the lowest condition factor has been omitted in calculating the means given in Table 2.

Table 2.

Length (mm) and Condition Factor of Lake Trout. Condition factor Calculated by Formula, $K_{FL} = (Wt\ (gm)/Lt^3) \times 10{,}000$. Tanks 1 and 2 Received Lake Water, Tanks 3 and 4 Received Well Water. Tanks 1 and 3 Received Diet of Smelt, Tanks 2 and 4 Received Balanced (Control) Diet.

June 4								July 9							
Tank 1		Tank 2		Tank 3		Tank 4		Tank 1		Tank 2		Tank 3		Tank 4	
Lt	K	Lt	K	Lt	K	Lt	K	Lt	K	Lt	K	Lt	K	Lt	K
168	117	165	169	150	84	156	107	163	94	182	187	150	67	169	144
160	145	184	171	164	108	183	158	170	152	198	194	165	73	191	186
164	175	190	194	160	129	195	142	188	198	214	238	169	137	211	198
186	208	199	207	193	172	183	167	216	216	206	285	209	128	204	223
201	196	190	244	210	145	194	162	216	246	222	252	214	157	212	216
247	292	205	212	195	189	204	173	259	277	222	256	211	189	224	219
240	325	216	221	216	176	211	186	257	313	239	284	217	210	229	225
270	325	219	215	213	209	208	206	297	354	222	335	235	228	228	240
295	331	206	245	289	293	273	274	321	351	244	277	306	278	290	302
Means								Means							
210	238	201	214	205	178	206	183	229	251	221	265	216	175	224	226
								Change from June 4 to July 9							
								19	13	20	51	11	−3	18	43

Condition factors vary among fish according to several characteristics, one of which being size (cf. Lagler, 1956.) It is desirable that the trout in all tanks be about the same length in order that condition factors be comparable. Data from the largest trout in tank 1 have also been omitted in calculating the means shown in Table 2. The mean values for tank 1, then, are based on seven individuals while those for the other tanks are calculated from eight fish.

Discussion

Two comparisons of the data in Table 2 immediately suggest themselves, (1) a comparison within a water supply between diets, (2) a comparison within a diet between water supplies. Both should be approached with caution.

For the first comparison, completely aside from considerations of thiaminase, the food items, smelt, trout pellets, pork liver, are different from each other in palatability and nutritional value. Differences in growth and condition of fish fed these diets may be attributable in part to these differences. Liver in particular, because of its palatability and/or its proportions of various constituents, appears to be very conducive to growth. For example, Halver (1957) developed a complete diet containing given proportions of protein, fat and carbohydrate sources, minerals and vitamins. Of four groups of 1,000 each of chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), fry, two were fed the complete diet and two beef liver for 18 weeks. At the end of the period no abnormalities in mortality, food consumption, total blood cell counts, hemoglobin determinations, gill filament examinations or post mortem examinations of internal and external organs were observed in fish on either diet. Also, although particular attention was given to looking for vitamin deficiency symptoms, none was observed. The fish on both diets had healthy appetites and gave every indication of being healthy, yet the growth rates of the fish on the test diet were below those on the liver diet.

The lake trout received diets of either smelt or mainly trout pellets for one and a half months before they were weighed on June 4. The mean condition factors on that date for trout in well water, 178 for those on the smelt diet and 183 for those on the control diet, are not significantly different (Student's t test; 95% level). In lake water the mean condition factor of those receiving smelt, 238, was higher than that of those on the control diet, 214. Even though the four mean lengths shown for June 4 are not significantly different (F-test, 95% level), in lake water the trout receiving smelt were, on the average, almost a centimeter larger than those receiving the control diet. If the data for one more fish (270 mm long) in tank 1 are omitted, the mean length of the six remaining trout is 200 mm, virtually the same as the mean length shown in Table 2 for eight trout in tank 2. The corresponding condition factors are 224 (instead of 238) for tank 1 and still 214 for tank 2. With the effect of size eliminated then, the group receiving smelt were still in better condition than those on the control diet, however, these mean condition factors too are not significantly different (Student's t test; 95% level).

In the period before June 4 the trout in tanks 2 and 4 received a nutritious but relatively unpalatable diet. Their condition was not significantly different than that of trout receiving only smelt. Although the differences in condition factors are not significant, it is interesting to note that the condition of fish on the smelt diet in lake water (where it was eaten) was slightly better than that of the control diet; in well water, where thiamin deficiency symptoms were evident and little smelt was eaten, it was slightly worse.

It can be seen in Table 2 that in the following month, before the trout were weighed on July 9, there was an increase in length of the fish in all tanks. In tank 3 the increase was about half of that of the other tanks. In lake water the condition of trout receiving smelt improved, but in well water it did not. The control diet was changed in that period so that it consisted mainly of pork liver. The great improvement in condition of the trout in tanks 2 and 4 undoubtedly reflects that change to high liver content. In lake water the change in condition factor was about four times greater in fish receiving the control diet than in those receiving smelt, a change of 51 and 13 respectively. That difference is probably not related to palatability since both the liver and the smelt were eaten readily. However, the difference could be related to the nutritional quality of the two diets, such as the fact that liver contains twice the protein of fresh fish (cf. Phillips, 1963). Combs, et al. (1962) found that diets containing 25 percent protein produced significantly greater gains in weight and higher protein deposition in fingerling chinook salmon than diets with 20 percent protein.

A comparison of growth or condition factors within a diet but between lake and well water is subject to limitations because of differences in water temperatures. Any such comparisons that are made with the data in Table 2 indicate better conditions in lake water. The better growth or condition factors of trout in lake water are quite likely related in large measure to the fact that it was warmer.

It should be noted that even if the trout in tank 3 did not suffer a vitamin deficiency, it might be expected that their condition would be the poorest of the four groups of fish. Tank 3 received both the cooler of the two water supplies and, in that it lacked liver, the poorer of the two diets.

Conclusions

Even though comparisons among the four groups of fish in this experiment are complicated by the presence of such factors as different palatability of diets and different water temperatures, some conclusions concerning the effects of a diet of smelt on lake trout appear to be justified.

The trout in lake water receiving smelt (tank 1) gave no indication of suffering thiamin deficiency. No deficiency symptoms were ever observed in tank 1. Those trout had a better average condition factor on June 4, although not significantly better, than trout in the same water supply receiving a balanced diet. Between June 4 and July 9, the final month out of a total of two and a half months on the smelt diet, they grew in length and weight. The increase in length was virtually the same as that of other trout in the same water supply receiving mainly liver.

The trout in well water receiving smelt (tank 3) appear to have suffered thiamin deficiency, but it does not appear to have been severe. That they suffered the disease is evidenced by their exhibition of the symptoms of thiamin deficiency. Also, on June 4 those fish were in poor condition and shortly more than a month later on July 9, their condition had not improved. Throughout the entire experiment they were in water that was warmer than 7.2°C. (45°F.) and in the latter period the water averaged about 10°C. (50°F.) Under such circumstances the condition of healthy trout could be expected to improve. Since these fish practically ceased feeding after the first few days on the smelt diet, it is certainly likely that they suffered from malnutrition during the experiment. Such a result, however, may be considered a secondary effect of athiaminosis, the primary effect being a cessation of feeding.

The disease appears to have been mild because no mortalities occurred and indeed the symptoms characteristic of the latter stages of thiamin deficiency were not observed. In addition, between June 4 and July 9 fish in tank 3 grew slightly in length, if not in weight. It might be observed, with respect to the indications of only a mild form of vitamin deficiency disease in these fish, that other workers have found variable reactions among fish to conditions producing the disease. For example, Wolf (1942) found in one experiment that brown trout were more susceptible to the disease than brook or rainbow trout, and that one strain of rainbow trout was more susceptible than another. There is evidence too that some species are extremely immune to the disease (cf. Harrington, 1954).

Throughout the experiment the two groups of trout receiving the control diet in lake and well water, tanks 2 and 4 respectively, appeared healthy, and in the final month they grew in length and their condition improved.

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Early Importation and Distribution of Exotic Fresh Water Fish Species in Newfoundland

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Introduction

The early importation of foreign fish ova into Newfoundland fresh waters was initiated by the Newfoundland Game Fish Protection Society. The object of the Society which was founded in 1884 at St. John's was the encouragement of angling and the propagation and protection within the island of fresh-water game fishes. A lease from the Crown dated April 14, 1887, gave permission to the Society to operate a fish hatchery at Long Pond, near St. John's. The hatchery was transferred to Murray's Pond in 1900. The Society agreed to supply 10,000 fry annually as rent for the ponds.

Brown trout (*Salmo trutta* L.)

The first importation of trout eggs took place in January, 1886[1] when Lochleven ova (*Salmo trutta* L.) were imported from Scotland (McNeily, 1909). German brown trout (a variety of *Salmo trutta*) were introduced in 1892 and English brown trout (probably also *Salmo trutta* L.) were imported in 1905 or 1906 (Frost 1940).

At present brown trout are widely distributed on the Avalon Peninsula and they have extended their range to some extent beyond the Avalon and along the North side of Trinity Bay (Scott and Crossman, 1964). Specimens were also taken in 1964, on the east side of the Burin Peninsula (personal communication Mr. John Pippy, St. John's).

Rainbow trout (*Salmo gairdneri* Richardson)

A shipment of rainbow trout was imported in 1890[1]. These originated in the State of New York as did all rainbow importations that followed. Fish from the 1890 shipment were distributed in ponds near St. John's. Importations followed almost annually until 1901 when the Society discontinued this practice and obtained eggs from established parent stock.

As of 1901 the Society extended its range of distribution of rainbows on the Avalon Peninsula, and in 1905 yearlings were conveyed to the Terra Nova River. An even wider distribution followed in later years. Beyond the Avalon Peninsula, however, few if any authentic reports are available to indicate that rainbow trout

[1] The *Evening Herald*, St John's, Nfld., Feb. 23, 1892.

survived these plantings. Meanwhile on the Avalon Peninsula where restocking has continued almost annually, a population of rainbow trout is now well established and provides considerable angling activity. The hatchery at Murray's Pond continues in operation.

Salmon-trout ova

The Society imported salmon-trout ova in 1886[2]. Fry from this stock were distributed on the Avalon Peninsula. The Society's Annual Report for 1893 contains the extract: "In 1893 Sir John Thompson, Prime Minister of Canada, in response to the application of the Game Fish Protection Society sent a gift . . . 100,000 ova of the magnificent salmon trout which attain such a large size in Canadian lakes. They arrived in good condition . . . but only a small percentage were hatched out and planted." Mr. Harry Walters (1954, unpublished) suggests that the species referred to here is lake trout *(Salvelinus namaycush)*. There is no evidence to indicate that introductions of Laketrout were successful (Scott and Crossman, 1964).

Lake Whitefish (*Coregonus clupeaformis* Mitchill)

Scott and Crossman (1964) have given an up-to-date review of the importation and distribution of whitefish in Newfoundland. Whitefish were first introduced 1886[3] and later in 1895. At least one of these plantings was successful for anglers have reported whitefish in Hogan's Pond on many occasions. In 1960 Scott and Crossman (Scott and Crossman, 1964) netted 14 whitefish in the same pond and the author of this report netted more than 100 in Hogan's and nearby Mitchill's Pond during the summer of 1965.

American smelt (*Osmerus mordax* Mitchill)

The American smelt is a common species around the inshore waters of Newfoundland occurring especially in shallow and estuarine waters whence they run into streams to spawn. The landlocked form is also known to occur in many Newfoundland lakes and ponds. In its Annual Report for 1893 the Society reported that waters had been stocked "with food fish such as Smelt and Stickleback . . ." It is reported (Scott and Crossman, 1964) that smelt eggs were again imported in 1895.

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[2] *The Evening Herald*, St. John's, Nfld., Feb. 23, 1892.

[3] *The Evening Herald*, St. John's, Nfld., Feb. 23, 1892.